Dacus dorsalis Hendel, in Hawaii

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Since the discovery of the oriental fruitfly, *Dacus dorsalis* Hendel, in Hawaii, in May of 1946, it has received more attention from entomologists here than any other insect. A great deal of information has been collected in regard to the fly's identity, geographic range and distribution, life-history, habits, hosts (ecology), control, both artificial and biological, economic importance, etc. This information I have collected and put into form for publication as a report of the work that has been the main occupation of myself and associates during the past year or two. In view of the great interest displayed in the matter by the public and profession alike, I thought it might be an appropriate subject for the presidential address this year. I am not, however, going to tire you with the full details, but will give you as briefly as possible the essential facts related in the report.

Identity of the fly. It was apparent at once on examination of prepared specimens that the fly belonged to what is known as the "*ferrugineus* complex" and fortunately we had in our library Shiraki's work on the fruit insects of Formosa containing a brief account of *Dacus ferrugineus* var. *dorsalis* with illustrations in color from which we could, to our own satisfaction at least, determine the identity of our invader. Later on it was desired to have confirmation of our determination by a recognized expert and specimens were sent to Dr. Alan Stone of the U. S. National Museum, who verified the identification by comparing the specimens sent in with material obtained from the Berlin Museum where Sauter's Formosan insect collections repose. It is not believed there is any question at present about the identity of the fly that is doing so much damage to our fruits, but it is still an unsettled point whether the species or variety *dorsalis,* which was described by Hendel from specimens collected in Formosa, is extensive or restricted in range. If *dorsalis* is considered as a component of the *ferrugineus* complex, there is no question about it or its closely allied forms ranging from India in the west to Australia in the east, and from Java in the south to Formosa or even Kyushu in the north. Bezzi in his monograph on the Philippine trypetids lists *dorsalis* as occurring in a number of oriental countries but we have been unable to identify it positively in the collections from the Orient we have had. The question is more or less academic for the present.

While the presence of *dorsalis* in Hawaii was not recognized until May 10th, 1946, there seems to be no question about its having been here unrecognized more than a year previous to that date. O. C. McBride has stated that he found one female specimen of *dorsalis*

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amongst 22,500 flies reared or collected between April and July 1945, and in view of the fact that the fly has been known to be on Saipan for a decade or more, and that our armed forces returned to Hawaii after the conquest of this island, circumstantial evidence points to their being responsible for transporting the insect to our shores, probably in infested fruits.

Life history. There is nothing unusual in this fly's development. In cage rearings in our laboratory a period of 16 days was required for development from deposition of the egg to emergence of the adult fly, in bananas; 23 days for similar development in papaya, both records made in the summer months when development is expected to be fastest. Duration of the different stages, in the spring months, averaged less than 2 days for the egg, 16 days for the larvae, 9 days for the pupae, but in one rearing, larval development was completed in 9 days. This stage shows greatest variation, and apparently under some conditions can be greatly prolonged. We found the length of life of the adult fly unpredictable but as a general rule flies can be maintained alive much longer when properly fed and cared for. In one experiment begun with 50 females and 50 males, all fed on papaya juice diluted with water and sweetened with honey, highest mortality occurred in the third week of the experiment; one individual, a female, lived through 86 days. We have found the preoviposition period to range from 8 to 16 days, although another investigator states that 29 to 32 days (in Sept. and Oct.) and 34 to 39 days (in May and June) were required to mature the eggs. One worker has recorded observing mating an hour after darkness had set in, 22 days after the emergence of the flies. In an experiment begun with gravid females to check on oviposition habits and capacity we observed that even with ripe fruits the fly carefully explored the surface for soft spots where the ovipositor could be inserted readily, and advantage was taken of bruises, cracks and very thin areas of the skin. Where there was internal pressure to oviposit, eggs often to the number of several hundreds were laid at one time but ordinarily the number was limited to less than 10. Another investigator states that working with flies individually confined the highest daily total obtained was 37 eggs and the highest 7-day total for an individual fly was 101 eggs. Where in nature a larger number of eggs is found in one pocket or break in the skin of the fruit, it is realized it may be the deposit of several females. Early in our experience with this fly it was discovered that citronella oil exerts a decided attraction for the male flies. This peculiar quality of the oil has little significance in control operations and except to help judge the effectiveness of poison sprays in reducing fly populations in a given locality or estimating size of populations the oil has little practical use. It should be mentioned here that examination of thousands of reared specimens of the fly showed that males and females maintained about even numbers in the count. Flies trapped with citronella oil, being overwhelmingly males, presumably represent only about half the population. Another experiment planned

to obtain a check on the percentage of flies successfully passing through developmental stages on the basis of host fruit in which development took place, gave such varying results—from 37 per cent for *Opuntia* fruits to 99 per cent for papayas—that little significance is seen in the results obtained.

Many of the observations made by Koidsumi and Shibata in their ecological studies of the fly in Formosa have been verified here and I believe it is worth while to include here some of their findings as given in the review of their work which appeared in the Review of Applied Entomology. They found the adult flies more active than those of *D. cucurbitae* and believed it necessary to provide more space for them to move in when observing their habits. Emergence of the flies was observed to occur generally before noon and they believed the flies to be most active at 77-86° F., becoming dormant when the temperature dropped below 68° F. They found the flies lived about a week, without ovipositing, when given water only, and for a month when fed on honey. They lived much longer and laid eggs when fed on banana and other fruits. Oviposition began 20 days after emergence in summer, 25-60 days in autumn and 100 in winter, when the flies were fed on orange juice. Females that were about to oviposit drove away others from the fruits. According to these observers *dorsalis* females lay fewer eggs in a fruit than *cucurbitae,* only 20-30 larvae being usually found even in a large fruit as compared with 200-300 of the latter species, a single egg cavity generally containing 5 to 10 eggs. The number of eggs laid by a single female is usually 500 and sometimes 1000. Even citrus fruits that are strongly acid (pH 2.2-2.7) were sometimes attacked and larvae were able to mature in them. Flies in captivity laid eggs in ripened papaya, bruised pineapple, banana, pear, apple and persimmon and the larvae matured in all except the last two, although they are not usually attacked in the field. Captive flies laid eggs in lemon but the eggs or newly hatched larvae succumbed in the unfavorable environment. In the northern part of Formosa the flies remained dormant in winter. Though emergence from the pupae was observed to take place, eggs and larvae did not develop.

One of the most striking evidences of *dorsalis'* superlatively aggressive qualities is the gradual disappearance of the Mediterranean fruitfly *Ceratitis capitata* (Wied.). In regions like the Honolulu city area where fruit-bearing trees are everywhere present and *dorsalis* populations high, *C. capitata* has totally disappeared. This is not a notion; one has only to consult the year's record of rearings from fruit collected in Honolulu to see how nearly accurate this statement is.

Much time has been spent in collecting host fruit records for *dorsalis.* The list far surpasses in length the list of *C. capitata* hosts. Ninety-three fruits are now listed and most of the common fruits of the islands are included. The cucurbit fruits are notice-

ably absent and the common assertion that the fly shows no selectivity is not entirely true. Reference has been made earlier to a record of rearings of flies from various fruits. This record covers more than a year's study (reported on monthly) of the number of flies reared from 44 different fruits and data can be obtained from it on the number of flies per fruit and the number per pound in any month of the year when this fruit was available in a condition to become infested. Of course most of the records pertain to the four or five commercial fruits (mango, avocado, papaya, banana, fig) and to several wild fruits which are extremely common (guava, kamani and *Eugenia* spp.). It is believed that by and large the heaviest fruit production occurs in the summer months and one of the commonest fruits at this time is the mango. *Dorsalis* has ruined the mango crop for several years and in view of the great number of seedling trees everywhere the fly will surely continue to build up large populations every summer. It was very noticeable in the past summer how decidedly the fly population dropped when the mango fruit season was over. There are some data in this record showing a positive relationship between the size of the fruit and the number of flies produced but it is not consistently evident throughout, mainly because of other factors entering into consideration. The record will be particularly valuable when parasites and predators introduced to control the fly begin to have an effect on the size of the populations. Fortunately for the success of the biological control project there are some fruits both wild and cultivated that mature regularly in the fall and winter months and some that have early and late fruiting varieties and some of the most useful fruits for the propagation of the parasites often bear several crops during the year according to the vagaries of weather conditions and also where irrigation is practiced. My observation is that fruits must be approaching maturity before oviposition succeeds in it. No doubt attempts are made by flies heavy with eggs to oviposit in immature and green fruits but if the fruit is hard the skin cannot be readily penetrated; if ripening has not begun the eggs will be expelled, or crushed, or drowned in the sap, or vitiated by some deleterious agent such as a protolytic enzyme.

Economic importance of the fly. Although the oriental fruit-fly attacks so many fruits it is easier to name the ones it is not reared from than those it is, the economic importance of the fly is posited in its destructiveness to the commoner marketable fruits, such as the mango, avocado, banana, papaya and fig, and its menace to fruit growers in California and the American states of the Gulf Coast, where citrus fruits, a favored host in Formosa, are the big item in fruit production. Fortunately, it does not normally attack the pineapple, the one fruit of really great economic importance in Hawaii—60 million dollars yearly—(it has been reared from overripe pineapple both here and in Formosa). Export of fresh fruit, even pineapples and bananas which previous to 1940 were shipped to the west coast of America in considerable volume,

is now prohibited by federal quarantines unless the fruit is treated in such a way that all developmental stages of the fly—eggs, larvae, pupae—are killed, an expensive procedure seriously limiting its application. Besides the spoilage in edible fruit caused by injury to it by the fly in depositing its eggs and the worms developing therefrom in feeding on the pulp—a loss which can be great in tropical and semitropical climes with a fly of *dorsalis'* potentialities —injury has also been observed to the blooms of orchids and gingers which emit fragrant odors, attracting the male flies of *D. dorsalis*. The injury is in the nature of a spotting which results from tissue destruction beneath droplets of regurgitated liquid food dried too rapidly by the sun, and affecting adversely the saleability of the flowers.

Measures taken to control the fly. Mechanical. Bagging fruit to prevent access to it by the ovipositing female, is a very practical measure but it has its limitations. Mangoes, avocadoes and figs can usually be covered with bags and even tomatoes and other small fruits are similarly protected. Trapping has generally given poor results, as a good bait or lure has yet to be found.

Chemical. It has been found by experiment that wettable DDT spray gives protection to ripening fruit for at least one week. This is considered much safer than the old Mally formula of arsenic, molasses and water.

Many of the control measures found suitable in other fruit growing countries appear to be inapplicable here mainly on account of the abundance of wild fruits present, often growing in inaccessible places, which keep the fly population going in spite of any repressive measures taken. For instance, clean culture; this familiar procedure was given a trial when the Mediterranean fruitfly appeared in Hawaii in 1910-11 but proved ineffectual. With its failure recourse was had to biological control.

Biological control. Considerable was already known about fruit fly parasites and predators in the Orient from previous exploration there, and in numerous consignments of fruitfly material from the Philippines and Malaya three opiine parasites and one tetrastichine parasite have been generally reared. These are *Opius longicaudatus* (Ashmead), *O. persulcatus* (Silvestri), *O. incisi* Silvestri and *Syntomosphyrum indicum* Silvestri. The first named has been successfully propagated and many thousands liberated on the principal islands. Its recovery from the field has been effected in many instances on Oahu and its establishment is well nigh certain. The others have all been reared in *dorsalis* larvae but have not reproduced very well. Predators are also being introduced, particularly staphylinid beetles (one is being propagated and liberated from time to time). It is believed that eventually an effective control of the fruitfly will be obtained by the various means above detailed.